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FEATHER PROCESSING METHOD AND PRODUCT

by

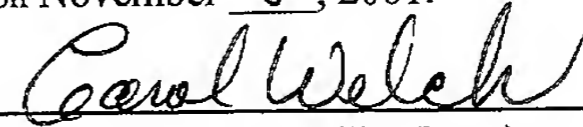
BARRY ALLEN GRIFFITH
3391 ESSEX
FAYETTEVILLE, WASHINGTON
COUNTY, AR 72704

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CAROL WELCH

(Name of Person Mailing Paper)



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REFERENCE TO CO-PENDING APPLICATIONS

BACKGROUND OF THE INVENTION

[001] The present invention relates to processing methods for feathers, particularly poultry feathers, and to feather products produced therefrom.

[002] In the United States alone, approximately four billion tons of feathers are produced in poultry processing operations each year. Almost all of these feathers are rendered to produce a powdery, complex protein commonly used as a livestock feed additive. Unfortunately, the costs of such rendering processes typically equal or exceed the economic value of the rendered product.

[003] Although poultry feathers have certain characteristics and properties which would be desirable for other applications, the ability to use feathers in such applications has heretofore been prevented by such things as (a) the nonhomogeneous structure of the feather, (b) the difficulty and cost of adequately cleaning poultry feathers to remove proteins, bacteria, and other contaminants, (c) the difficulty of preventing short term and long term decay of the feather materials, and (d) the tendency of feather materials to produce undesirable odors. For example, in their article entitled "Feather Fiber Reinforced Concrete," *Concrete International*, June 1994, S. A. Haoush and M. M. El-Hawary suggest that poultry feathers could be used as an additive for producing lightweight concrete. However, Haoush and El-Hawary fail to disclose any effective method for washing, cleaning, screening or drying feather materials and acknowledge that a need exists for an effective means of treating feathers to prevent short term and long term decay.

[004] In addition to the application suggested by Haoush and El-Hawary, U.S. Patent No. 641,923 suggests using a material consisting of a mixture of lime, manganese chloride, calcium chloride, and feathers as a covering for boiler surfaces. U.S. Patent No. 708,003 discloses a rubber substitute material formed by

mixing crude rubber dissolved in benzene or gasoline with sulphur,
whiting, gum-Arabic and feathers which have also been washed with
benzene. U.S. Patent No. 1,763,411 discloses an artificial golf
course covering formed by mixing cut feathers with crankcase oil,
5 oil paint, or tar.

[005] U.S. Patent No. 5,705,030 discloses a method of making
fiber from feathers comprising the steps of: (a) collecting raw
feathers, (b) washing the feathers in a polar, water soluble,
organic solvent (ethanol), (c) repeating the ethanol washing step,
10 (d) removing the solvent from the feathers, and then (e) removing
the fibrous components of the feathers from the shafts (quills) of
the feathers by mechanical shredding or shearing. The patent
suggests that the feather fiber product might be useful for
producing insulation materials, fabrics, paper-like products,
15 extrusions, and composite articles.

[006] The entire disclosure of U.S. Patent No. 5,705,030 is
incorporated herein by reference.

[007] Although more promising than some other feather
processing methods suggested heretofore, the ethanol washing
20 process of United States Patent No. 5,705,030 has significant
shortcomings. For example, volatile organic solvents such as

ethanol are relatively expensive and present obvious safety, handling, processing, and environmental costs, requirements, and concerns. In addition, the process of United States Patent No. 5,705,030 is relatively complex in that it requires two solvent washing steps, a solvent removal step, and a drying step, all of which are conducted prior to mechanically shredding or shearing the feathers.

SUMMARY OF THE INVENTION

[008] The present invention provides a feather processing method which satisfies the needs and alleviates the problems discussed hereinabove. The inventive method provides an inventive feather product material which will not decay or produce objectionable odors and which is well suited for producing end products such as insulation materials, fabrics, filters, egg cartons, other molded articles, paper, and other paper-like products. The inventive feather material is also well suited for producing extrudates and composite materials for construction and other uses.

[009] In one aspect, the inventive feather processing method comprises the step of reducing poultry feathers (e.g., by refining

and/or pulping) in the presence of an aqueous liquid carrier solution. The aqueous carrier solution preferably comprises hydrogen peroxide, bleach, or detergent in a concentration effective for cleaning and sanitizing the feathers during the reducing step. Alternatively or in addition, the reduced feather material could be cleaned and sanitized by stirring, mixing, or otherwise agitating the feather material in an aqueous hydrogen peroxide solution or detergent solution after the reduction step.

[0010] In another aspect, the present invention provides a method of processing feathers comprising the step of reducing the feathers in a reducing apparatus selected from the group consisting of at least one refiner, at least one pulper, and combinations thereof. The present invention further provides products produced by the inventive method.

[0011] In another aspect, the present invention provides a method of processing feathers comprising the step of reducing the feathers in the presence of a cleaning agent selected from the group consisting of hydrogen peroxide, detergent, bleach, and combinations thereof. The inventive feather processing method preferably comprises the step of reducing the feathers in the

presence of hydrogen peroxide, a de-inking material, or a combination thereof.

[0012] In yet another aspect the present invention provides a method comprising the steps of: (a) adding a reduced paper material to a reduced feather material to form a combined reduced material and (b) forming a product from the combined reduced material. The present invention also provides products produced by the inventive method.

[0013] Further objects, features and advantages of the present invention will be apparent to those skilled in the art upon examining the accompanying drawings and upon reading the following description of the preferred embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] Figure 1 is a block diagram which schematically illustrates an embodiment 2 of the inventive feather processing method and system.

[0015] Figure 2 is a block diagram which schematically illustrates an alternative embodiment 100 of the inventive feather processing method and system.

[0016] Figure 3 schematically illustrates another alternative embodiment **150** of the inventive feather processing method and system.

[0017] Figure 4 schematically illustrates another alternative embodiment **200** of the inventive feather processing method and system which includes a sheeting process.

[0018] Figure 5 schematically illustrates yet another alternative embodiment **250** of the inventive feather processing method and system which includes a molding process.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0019] An embodiment **2** of the inventive feather processing method and system is schematically illustrated in Fig. 1. The inventive system can be employed for processing generally any type of feathers. Inventive system **2** is particularly well suited for processing chicken feathers and other types of poultry feathers.

[0020] In inventive system **2**, feathers from a poultry processing operation or other source are delivered to an infeed system **4**. Infeed system **4** can be, for example, a typical infeed system of the type used for feeding raw feather materials to rendering plants. As will be understood by those skilled in the

art, such systems are capable of continuously delivering feathers to the processing system at a controlled or semi-controlled rate.

[0021] If necessary, the infeed system 4 can deliver raw, dirty feathers to an area 6 where any other parts (e.g., heads and feet) and any foreign objects (e.g., metal objects, gloves, etc.) are removed. As will be understood by those skilled in the art, generally any method of removing such parts and foreign objects can be used. For example, area 6 could comprise a water-filled, dissolved air flotation (DAF) tank wherein dissolved air is used to physically separate meat parts and foreign objects from the raw feathers. Due to inherent buoyancy differences, any heads, feet, or other meat objects can be removed by adjusting the rate of air addition to the tank such that the meat objects travel through the tank at a rate of speed which is substantially slower than that of the feathers, thus causing the meat objects to be separated from the feathers by a divider plate or other separator appropriately positioned within the tank. Metal objects, on the other hand, separate from the raw feathers by simply dropping into a trap provided in the bottom of the tank.

[0022] Alternatively, or in addition, foreign material can be removed in step 6 using metal detectors, centrifugal (e.g.,

cyclone) cleaners, and/or other devices or systems known in the art.

[0023] From separation system 6, the wet, raw feathers are preferably conveyed to an apparatus 8 capable of reducing the wet, raw feathers to a produce a refined and/or pulped feather material. Apparatus 8 will preferably be one or a plurality of refining and/or pulping machines of the type commonly employed in the paper industry for producing pulp from recycled paper. As will be understood by those skilled in the art, the pulping/refining step can be conducted in either a continuous or batch manner. As used herein, the terms "refiners" or "refining" machines also include disc mill apparatuses.

[0024] If a pulper is used in step 8, it will preferably be of the type used for processing recycled paper. The pulper will most preferably be a high shear pulper of the type having a rotor and stator assembly with a close tolerance in the defibering zone.

[0025] An example of a commercially available pulper well suited for use in the present invention is the TORNADO pulper available from Bolton Emerson. Another suitable, but somewhat slower, unit is available, for example, from Thermo Black Clawson.

[0026] Step 8 of the inventive process 2 will preferably be performed using one or more refining machines of the type used for processing recycled paper. The refining apparatus employed in step 8 will most preferably be a disc mill type refiner of either single or double disc design. As will be understood by those skilled in the art, various alternative types of discs can be used in such apparatus to obtain generally any type and degree of grinding, shearing, shredding, pulverizing, rubbing, fluffing, or other refining desired.

[0027] I have discovered that the refiners and pulpers used in the present invention are unexpectedly and surprisingly effective for processing feather materials. These devices are well suited for handling the inherent structural strength of the feather materials and for overcoming the tendency of such materials to clump together. The devices thus efficiently and economically produce a consistent, uniform product of higher quality. The devices can also handle large volumes of feathers even with some foreign materials contained therein.

[0028] In inventive system 2, the feathers are preferably processed in the refining or pulping apparatus 8 in the presence of an aqueous liquid carrier solution comprising one or more cleaning

agents. Examples of suitable cleaning agents include, but are not limited to: solvents (preferably inorganic solvents such as hydrogen peroxide); detergents; bleach (preferably a chlorine bleach); and surface acting surfactants. If desired, further additives such as antibacterial agents, deodorizers, pesticides, surfactants, or other agents can also be included in the carrier solution. The particular cleaning agent(s) and additives used can be selected, for example, to achieve or create desired shelf-life, structural properties, surface characteristics, bonding sites, and other results for the refined product.

[0029] Inventive system 2 includes: a tank or other container 12 wherein the cleaning agent or a cleaning agent solution is stored; a conduit 10 (typically including a metering pump or other suitable metering device (not shown)) for delivering the agent or solution to the refining or pulping apparatus 8; and a conduit 14 for delivering recycled water to refiner/pulper 8 from a wastewater treatment system 16.

[0030] The amounts of the cleaning agent, recycle water, and/or fresh water delivered to refiner or pulper 8 are preferably controlled for effectively carrying, cleaning, and sanitizing the feathers during the reducing operation. Thus, the feathers are

cleaned and sanitized while they are being ground, chopped, or otherwise reduced in refining or pulping apparatus 8. Alternatively, the feather material can be cleaned, sanitized, etc., after refining and/or pulping as discussed hereinbelow.

5 [0031] The concentration of the cleaning agent within refining or pulping apparatus 8, the residence time of the feathers within refining or pulping apparatus 8, and the degree to which the feather material is recycled through refining or pulping apparatus 8 can be varied as necessary to obtain the particular end product
10 desired. Relevant factors include, for example, the size, structure and contaminant levels of the raw feather feed material and the desired size and purity of the resulting reduced product.

15 [0032] To carry the feather material and to obtain the degree of reduction, cleaning, and sanitizing necessary for the reduced product, sufficient cleaning agent and water will preferably be added to the refiner/pulper 8 such that the volume ratio of liquid carrier solution to feathers within the apparatus is within the range of from about 100:1 to about 1:1. Regardless of the particular cleaning agent(s) employed, the volume ratio of carrier
20 solution to feathers in refining or pulping apparatus 8 will more

preferably be in the range of from about 50:1 to about 2:1 and will most preferably be about 19:1.

[0033] If the cleaning agent employed in the inventive process is hydrogen peroxide, bleach, a surface acting surfactant, or a combination thereof, an aqueous solution thereof stored in tank 12 or otherwise used in the inventive process will preferably have a cleaning agent concentration in the range of from about 35% to about 50% by volume based upon the total volume of the solution. In addition, the concentration of hydrogen peroxide and/or bleach in the resulting total aqueous carrier solution in refiner or pulper 8 will preferably be in the range from about 200 to about 5,000 ppm by volume. The concentration of hydrogen peroxide, surfactant, and/or bleach in the aqueous liquid carrier solution will more preferably be in the range of from about 300 ppm to about 3,500 ppm by volume. The concentration will most preferably be about 2,500 ppm by volume for hydrogen peroxide or about 500 ppm by volume for surface acting surfactants or bleach.

[0034] If, on the other hand, the cleaning agent employed in refining or pulping apparatus 8 is a detergent, the concentration of detergent in the carrier solution will preferably be the same as

discussed hereinbelow concerning the refining or pulping apparatus
106 of embodiment 100.

[0035] For most applications, the feathers will preferably
have a total residence time within refining or pulping apparatus 8
5 in the range of from about five seconds to about 15 minutes. As
will be understood by those skilled in the art, multiple passes
through apparatus 8 can be employed if desired. Some typical
refining machines require from about five to about 60 seconds per
pass. The temperature of the material within pulping or refining
10 apparatus 8 will typically be in the range of from about 60°F. to
about 160°F.

[0036] In addition to cleaning and sanitizing the feather
material, the use of a hydrogen peroxide solution in the inventive
process can have a desirable bleaching and whitening effect on the
15 feather material. Moreover, in contrast to the use of organic
solvents as suggested heretofore, the use of dilute aqueous
hydrogen peroxide solutions in accordance with the inventive
process does not create serious safety concerns and does not pose
significant risks for fires or explosions. Additionally, rather
20 than creating significant waste treatment and environmental
problems, the available oxygen provided by the hydrogen peroxide

assists the wastewater treatment system 18 by reducing the system's biological oxygen demand (BOD) level. BOD levels are monitored and restricted by the EPA and by state and local environmental authorities.

5 [0037] Following the reducing step 8 and depending upon the amount of particle reduction and/or other characteristics necessary for the final product, the inventive process can also optionally include one or more additional reduction and/or refining steps 20. Examples of devices and systems 20 which could be used for further
10 reducing and/or otherwise refining the feather pulp include, but are not limited to: linters; blenders; mills; choppers; centrifugal grinders; cleaners; and/or additional pulpers or refiners.

15 [0038] After the reducing step 8 and the optional refining step 20, the reduced feather product can be processed to separate the material into its fiber and quill components. Such separation could be conducted, for example, in accordance with the procedures explained in United States Patent No. 5,705,030 wherein the feather material is dried and then separated using, for example, a linter,
20 a cone separator, an organ separator, a comb/brush separator, or a combination of two or more such devices.

[0039] However, in inventive process 2, it is preferred that the wet material produced from refining or pulping apparatus 8 or optional refining step 20 be directly separated into its fiber and quill components using a hydraulic screen apparatus 22. Hydraulic screen apparatuses are readily available in the art and are commonly used, for example, for processing recycled paper. Typical hydraulic screen systems include pressure screens which, in this case, will operate to separate fiber material from quill material based upon size. The screen will typically comprise slots, holes, and/or other apertures which allow fibers of desired size to pass through while retaining all larger components. The slots, holes, or other apertures will typically have diameters or widths in the range of from about 0.001 to about 0.1 inches and will preferably have widths or diameters in the range of from about 0.005 to about 0.03 inches. Makeup water can be added to the hydraulic screen apparatus, preferably to the accept side thereof, to prevent clogging.

[0040] The separating apparatus used in step 22 of the inventive process will most preferably be a hydraulic screen apparatus of the type comprising either a vertical or horizontal pressure screen. In addition, the apertures contained therein will

preferably be slots having lengths in the range of from about 0.25 to about 1 inch.

[0041] If desired, the material retained by the pressure screen can optionally be recycled for additional processing in refining or pulping apparatus 8 and/or the optional reduction/refining step 20. Additionally, fiber material from hydraulic screen apparatus 22 can optionally be sent to other cleaners (e.g., of the type commonly used in the paper industry) wherein further unwanted quill material can be removed.

[0042] As illustrated in Fig.1, the separated fiber and quill products produced by the hydraulic screening system 22 are preferably each delivered to respective dewatering units 24 and 26. Each of dewatering units 24 or 26 preferably comprises either one or more decanter centrifuges, one or more centrifugal belt presses, a screw press, or a combination of such devices. Such devices are well known and commercially available in the art. Alternatively, the dewatering of the fiber and/or quill products could be accomplished using sheeting machines such as those employed for sheeting paper. Depending upon the type of device(s) used, the rotational speed of the decanter centrifuge, the squeezing force provided by the centrifugal belt press, etc. will preferably be

controlled to remove sufficient amounts of water from the quill and fiber products such that each of the resulting dewatered products has a moisture content of not more than 50% by weight. The water removed in dewatering units 24 and 26 is conducted to wastewater treatment system 16.

[0043] After dewatering, the separate fiber and quill products are preferably each delivered to respective drying units 28 or 30 wherein at least most of the remaining moisture is removed. Examples of suitable drying systems include, but are not limited to, forced air ovens, radio frequency ovens or dryers, tube dryers (e.g., jet tube dryers), or other comparable drying systems. The separate fiber and quill product materials can alternatively be dried using vortex or flash tube dryers or by sheeting the materials like paper and then drying in conveyor drying apparatuses. When dried, each of the fiber and quill products will typically have a final moisture content in the range of from about 5% to about 20% by weight, depending upon end use and/or customer requirements.

[0044] Alternatively, the quill material could be simultaneously dried and further ground as discussed hereinbelow

using a high velocity vortex dryer or could be ground using mechanical devices.

[0045] After drying, the respective fiber and quill products can be used directly for producing various products or can be packaged for shipment and further processing. For example, the fiber product can be compaction bailed, or rolled, and stored in polyethylene bags or wraps. Suitable types of compression bailers are available in the art and are commonly used, for example, for bailing synthetic fibers. The dried quill product can be packaged, for example, by sheeting into a role or by bailing.

Example 1

[0046] Chopped chicken feathers were continuously stirred in an aqueous hydrogen peroxide solution having a hydrogen peroxide concentration of 2500 ppm by volume. It was observed that such mixing for a period of from two to three minutes was adequate to remove substantially all fat and residual proteins from the feathers and to kill bacteria on the surfaces of the feathers and in the hollow areas of the fibers and quills. It was also observed that, the more violent the agitation, the less mixing time was required. Comparative tests revealed that essentially the same

amount of agitation was required for processing the feathers with ethanol.

Example 2

5 [0047] Additional tests were conducted by stirring chopped chicken feathers for up to 15 minutes in aqueous hydrogen peroxide solutions having hydrogen peroxide concentrations of up to 3500 ppm by volume. Examination of the resulting products using electron
10 microscope photographs revealed that, even when exposed to such higher concentrations of hydrogen peroxide for this extended period of time, the feathers did not experience any significant surface degradation.

* * * * *

15 [0048] Another embodiment **100** of the inventive feather processing system is schematically illustrated in Fig. 2. Like inventive system **2**, inventive system **100** can be used for processing generally any type of feathers and is particularly well-suited for processing chicken feathers and other types of poultry feathers. The feathers can be received from a poultry processing operation or
20 other source and are delivered to an infeed system **102** similar to infeed system **4** discussed above. The feathers are preferably first

conveyed through a metal detector **104** wherein any metal objects contained in the raw feather material are detected and removed.

[0049] From the metal detector **104**, the raw feathers are preferably conveyed to an apparatus **106** capable of reducing the raw feathers to a pulp-like material. As with apparatus **8** discussed above, the apparatus **106** will preferably be a refiner and/or a pulper of a type commonly employed in the paper industry to produce pulp from recycled paper. The pulping/refining step **106** can be conducted in either a continuous or a batch manner.

[0050] In embodiment **100** of the inventive system, the feathers are preferably processed in the refining or pulping apparatus **106** in the presence of an aqueous liquid carrier solution **108** comprising an amount of a cleaning agent as discussed above and preferably comprising a detergent. The amount of carrier and detergent or other cleaning agent delivered to refiner or pulper **106** are preferably controlled for effectively carrying, cleaning, and sanitizing the feathers during the reducing operation. The resulting action and turbulence within the refiner or pulper assists in washing fat and residual protein off of the feathers. Thus, the feathers are cleaned and sanitized while they are being ground, chopped, or otherwise reduced in refining or pulping

apparatus 106. As will be discussed hereinbelow, cleaning agent(s) can alternatively be employed after the reducing step.

[0051] The concentration of detergent or other cleaning agent within pulping apparatus 106, the residence time of the feathers within refining or pulping apparatus 106, and the degree to which any feather material is recycled through refining or pulping apparatus 106 can be varied, in a manner similar to that discussed hereinabove with respect to refining or pulping apparatus 8, to obtain the particular end product desired.

[0052] To obtain the degree of reduction, cleaning, and sanitizing necessary for the pulp product and assuming that a detergent is used, sufficient water and detergent will preferably be added to refiner or pulper 106 such that (a) the volume ratio of liquid carrier solution to feathers within the refiner or pulper is in the range of from about 100:1 to about 1:1 and (b) the concentration of detergent in the aqueous carrier solution is in the range of from about 2 to about 20 pounds per ton of raw feathers. The volume ratio of carrier solution to feathers in refiner or pulper 106 will preferably be in the range of from about 50:1 to about 2:1 and will most preferably be about 19:1.

[0053] If, on the other hand, the cleaning agent employed is hydrogen peroxide and/or bleach, the concentration of the agent in the carrier solution will preferably be the same as discussed hereinabove concerning the refining or pulping apparatus 8 of embodiment 2.

[0054] For most applications, the feathers will preferably have a total residence time within refining or pulping apparatus 106 in the range of from about five seconds to about 4 hours and will most preferably have a total residence time of at least 5 minutes. In the same manner as discussed hereinabove with regard to refining or pulping apparatus 8, multiple passes through refining or pulping apparatus 106 can be employed if necessary or desired. The temperature of the material within refining or pulping apparatus 106 will typically be in the range of from about 40 to about 160°F.

[0055] The detergent employed in the various embodiments of the invention discussed herein will most preferably be a wetting agent of the type providing emulsification of fats, oils, and greases as well as general soil detergency. An example of a commercially available wetting agent of this type particularly well suited for use in the inventive process and system is FIBERWET DI,

available from Steen Research, Inc. FIBERWET DI comprises a mixture of silicates, ethylenediamine tetraacetic acid, sodium, xylene sulfonate, sodium octane sulfonate, sodium laureth modified with 3 mole of ethylene oxide, and alkaryl ether phosphates.

5 [0056] As with embodiment 2, further additives such as antibacterial agents, deodorizers, pesticides, surfactants, or other agents can optionally be added to the carrier solution employed in embodiment 100. Further, the reducing procedure of inventive process 100 can also include one or a plurality of
10 additional reduction and/or refining steps depending upon the amount of particle reduction desired and/or other characteristics necessary for the final product. Examples of devices and systems which could be used for further reducing and/or otherwise refining the reduced feather material include but are not limited to:
15 linters; blenders; mills; choppers; centrifugal grinders; and/or pulpers or refiners.

[0057] Following the reducing step 106, the wet reduced feather material will preferably be conducted through a series of centrifugal cleaners 110. Centrifugal cleaners of the type
20 commonly used in the paper industry are particularly well suited for use in the present invention. The centrifugal cleaners 110 will

most preferably be forward centrifugal cleaners. Cleaners of this type are commercially available, for example, from Posiflow or Uniflow. The cleaner will preferably employ a small nozzle producing a relatively high pressure drop (most preferably a pressure drop in the range of from about 5% to about 30% from inlet to outlet).

[0058] The centrifugal cleaners will readily remove any contaminants remaining in the reduced feather material such as leg skin, parts of the head, eyes, etc. and will also remove most of the solution remaining in the reduced feather material. Although a single centrifugal cleaner **110** could be used, the reduced feather material will preferably be conducted through a series of at least two centrifugal cleaners **110**.

[0059] The wet, reduced feather material will preferably next be pressed to further remove most of the water and detergent solution remaining therein. Examples of mechanical presses **112** particularly well suited for use in pressing the wet reduced material are screw presses of the type commonly used in the paper industry for dewatering pulp and sludge fiber. Such devices are commercially available from Vincent Corporation, Dupps company, Press Technology, and others.

[0060] The pressed feather pulp material is conveyed into a rinse tank 114 where clean water is used to rinse away any remaining cleaning agent, fat, or protein substances. The rinse tank is stirred or otherwise agitated (using, e.g., paddles or any other type of agitation devices or systems) in some manner in order to keep the reduced feather material in suspension.

[0061] The temperature of the rinse water in rinse tank 114 will typically be in the range of from about 40 to about 160°F. To keep the rinse water clean, a slip stream will preferably be continuously removed from the rinse tank 114 (using, for example, a metering valve or a variable speed pump) and fresh makeup water will be continuously added. The rinse step can last anywhere from a few seconds to 20 minutes or more, as needed. If desired or necessary, the rinse water can optionally include additives such as hydrogen peroxide, bleach, sanitizers, deodorizing agents, etc.

[0062] After rinsing, the clean, reduced material is preferably separated into its fiber and quill components. Such separation can be conducted using any of the devices discussed hereinabove for inventive system 2. As with inventive system 2, the separation step of inventive system 100 will preferably be conducted using a hydraulic screen apparatus 116 of the type

commonly used in the paper industry. The material retained by the pressure screen can optionally be recycled for further pulping or refining. Additionally, the fiber product from hydraulic screen apparatus 116 can optionally be sent to other cleaners of the type commonly used in the paper industry wherein further unwanted quill or other material can be removed.

[0063] As is also the case with inventive system 2, the fiber and quill materials separated in the hydraulic screen apparatus 116 of inventive system 100 are preferably each delivered to respective dewatering units 118 and 120 similar to the dewatering units 24 or 26 discussed above. As with dewatering units 24 and 26, examples of dewatering units 118 and 120 suitable for use in inventive system 100 include but are not limited to decanter centrifuges, paper sheeting machines, belt presses, screw presses, and/or generally any other type of mechanical or centrifugal press.

[0064] After dewatering, the fiber product material can be used directly or can be dried and packaged. The dryer 122 and packaging system 124 employed in inventive system 100 can be the same as any of the dryers 30 and packaging systems discussed hereinabove for inventive processing system 2.

[0065] The quill material from dewatering unit 120 can be processed in substantially the same manner as the quill material produced in inventive system 2. However, prior to packaging, the quill material produced in inventive system 100 will most preferably be dried in a high agitation dryer 126 such as a high velocity vortex dryer or a rotary drum dryer. The high agitation dryer will also operate to further grind the quill material into sphere-like or substantially spherical particles. Further, any fiber material remaining in the quill product will not be harmed by the dryer but will likely also be desirably shortened in length.

[0066] High velocity vortex dryers are known in the art. An example of a commercially available vortex dryer particularly well suited for use in the present invention is the TORNESH DRYER manufactured by Carrier Vibrating Equipment. As an alternative to high velocity vortex dryers, rotary drum dryers operating at accelerated rotational speeds and having additional baffle added thereto can be used.

[0067] Following the high velocity vortex dryer 126, inventive system 100 preferably includes a separation and collection system 128, preferably a cyclone separation and collection system, wherein the fiber and quill products produced in

vortex dryer 126 are separated from the air stream for packaging. Cyclone separation technology, or bag house technology, is particularly well-suited for this purpose in view of the fact that the fiber material and spherical quill product material will typically have significantly different flight characteristics, thus lending themselves to cyclone separation. The separated materials can be bagged, bailed, rolled, or otherwise packaged in a packaging system 130 in the same manner as the fiber and quill materials produced in inventive system 2.

* * * * *

[0068] As indicated above, the unique feather fiber material produced by the various embodiments of the inventive process can be used to produce many types of useful products, compositions, and articles. In producing such products, various types of additives can be mixed with the fiber material. Examples of such additives include, but are not limited to: mordants and dyes; binders; foaming agents; hardeners; chemical sizing agents; fillers; other plant, animal, or synthetic fibers; chemical cross-linking agents; wetting agents; and redox reagents.

[0069] The dried quill material produced by the inventive process can be used, for example, as a filler material, a binder material, a fertilizer, or an animal feed.

* * * * *

5 [0070] Another embodiment 150 of the inventive feather processing method and system is depicted in Fig. 3. Inventive embodiment 150 comprises an infeed step 152, a foreign material removal step 154, and a reducing step (preferably a refining and/or pulping step) 156 which preferably utilize the same equipment and
10 procedures as described above for steps 4, 6, and 8 of embodiment 2 and steps 102, 104, and 106 of embodiment 100. In embodiment 150, the cleaning agent from tank or container 158 can be added (a) via conduit 160 to the upstream side of refining or pulping apparatus 156, (b) via conduit 162 to the downstream side of
15 refining and/or pulping apparatus 156, and/or (c) via both conduits 160 and 162 to the upstream and downstream sides of apparatus 160. The cleaning agents and concentrations employed are preferably the same as those discussed above for embodiments 2 and 100.

[0071] Embodiment 150 next includes the step 164 of diluting
20 the reduced feather material with water 166. Sufficient water is preferably added to dilute the reduced feather material to a solids

concentration in the range of from about 0.05% to about 20% by volume. Sufficient water is more preferably added to dilute the reduced feather material to a solids concentration in the range of from about 0.08% to about 10% by volume solids and is most preferably added in an amount sufficient to dilute the reduced feather material to a solids concentration in the range of from about 0.1% to about 5% by volume solids.

[0072] The diluted reduced feather material is then preferably delivered to either (a) a hydraulic screen apparatus 168 of the type employed in step 22 of inventive method 2 or (b) a centrifugal cleaner of the type used in step 110 of inventive method 100. Regardless of which type of apparatus is used, the poultry feather material is separated by the apparatus 168 or 170 into a feather fiber product 172 and a quill product 174. If a hydraulic screen apparatus 168 is employed, additional water can be added to the fiber side of the device to prevent the hydrophobic material from clogging the screen.

[0073] If a centrifugal cleaner 170 is employed, the device can be desirably operated to further separate foreign material from the overall reduced feather stream. The centrifugal cleaners 170 can be configured to operate in single pass or multiple pass flow

and can be run in series, in parallel, or in a combined series/parallel arrangement. The use of centrifugal cleaners 170 may require a greater degree of refining/pulping than is required by hydraulic screen apparatus 168 to obtain the desired degree of fiber/quill separation.

[0074] The separated fiber and quill products 172 and 174 can be processed, dried and/or packaged in the same manner as discussed above in embodiments 2 and 100. The separated fiber and quill products 172 and 174 are preferably each prepared for additional processing by delivering the separated products to agitated slurry tanks 176 and 178 wherein appropriate bonding agents, dyes, and/or other materials can be added to condition or prepare the materials for further processing in steps 180 and 182. Processing steps 180 and 182 can be the same as those described in the various embodiments set forth hereinabove or can be sheeting or molding processes of the type described hereinbelow in embodiments 200 and 250 of the inventive process and system.

[0075] If employed, chemical bonding agents added to the reduced feather material can generally be any additives effective for providing increased wet strength during subsequent processing and/or permanently enhancing the dry strength of the resulting

products. For example, a combination of (a) a high molecular weight anionic acrylamide copolymer such as SC-3875, available from Steen Research, and (b) a medium weight acrylamide copolymer with a high degree of cationicity such as SC-3311, available from Steen Research, can be added to effectively bridge keratin strands in the feather material together to greatly enhance the shear resistance of the material and to significantly increase both the wet and dry strength thereof. Alternatively, or in addition thereto, a thermosetting cationic polyamide such as SC-211EO, available from Steen Research, can be added to the feather material to further increase both the temporary wet strength and the permanent dry strength thereof.

[0076] Examples of additional agents which can be added to the fiber and/or quill materials include: polymeric substrates such as POLYLINK-32, available from Steen Research, effective for improving the dust resistance and temporarily improving the water resistance of the material; polymeric substrates such as POLYLINK-33, available from Steen Research, effective for increasing the ultimate permanent water resistance of the formed feather structure and for preventing feather dusting; and a styrene butadiene emulsion such as POLYLINK-34, available from Steen Research,

effective for providing a permanent rubbery coating to formed articles and for increasing permanent water resistance and preventing feather dusting.

[0077] Examples of further additives which may be blended with the fiber and/or quill materials in steps 176 and 178 include, but are not limited to, flocculating agents and additives such as fungicides and known copper-based compounds effective for killing and/or inhibiting the growth of mold, fungi, and other bacteria in the final product.

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[0078] A fourth embodiment 200 of the inventive process and system is depicted in Fig. 4. Embodiment 200 preferably includes initial steps, processes, and systems 152, 154, 156, 158, 160, 162, 164, and 166 which are the same as the correspondingly numbered steps, processes, and systems described above in embodiment 150. Embodiment 200 is a feather sheeting process which can either include the step of separating the feather and quill materials or can utilize the refined feather material without separation of the fiber and quill components. In the embodiment 200 shown in Fig. 4, the fiber and quill components are used together without a separation step.

[0079] In the embodiment 200 depicted in Fig. 4, a dye 204 and suitable bonding agents 206 (such as those described hereinabove) and other additives (e.g., fungicides, flocculants, etc.) are preferably added to the reduced feather material 202.

5 Examples of dye materials suitable for use in the inventive process include but are not limited to dyes employed in the textile industry for wool products, anthraquinone based dyes, chromium metalized type dye materials, and combinations thereof.

10 [0080] The refined feather material produced in embodiment 200 can be used alone for producing a sheet product or can desirably be used in combination with a similarly prepared reduced paper material. In embodiment 200, a reduced paper material is prepared from pulp, craft, recycle, or other paper material using a refining and/or pulping process of the type known in the art. As
15 will be understood by those skilled in the art, the paper reduction process will preferably include: the step 208 of removing foreign material from the paper material; the step 210 of adding a suitable cleaning agent to the paper material; and the step 212 of refining or pulping the paper material using the same type of
20 refining and/or pulping devices described hereinabove.

[0081] The reduced feather material produced in step 206 and the reduced paper material produced in step 212 are each pumped or otherwise delivered to a slurry tank 214 where they are thoroughly blended together. The slurry tank 214 will preferably include a stirring system, an agitation system, or other type of mixing system known in the art.

[0082] The reduced material from tank 214 can be sheeted into a paper-like product using generally any type of sheeting apparatus employed in the art for producing paper and other paper products. The slurry delivered from tank 214 will preferably have a feather to paper weight ratio of at least 2:3 and preferably not more than 19:1. The slurry will more preferably have a feather to paper weight ratio in the range of from about 4:1 to about 9:1 and will most preferably have a feather to paper weight ratio of about 17:3. The slurry delivered from tank 214 will also preferably have an overall solids concentration in the range of from about 1% by weight to about 10% by weight. The slurry will more preferably have a solids concentration of from about 1.5 to about 7% by weight and will most preferably have a solids concentration of from about 3% to about 5% by weight.

[0083] The sheeting system employed in the inventive process will preferably be a system of the type employed for producing paper sheets from recycled paper material. As will be understood by those skilled in the art, the system will preferably be of the type comprising a forming box **216** having multiple vacuum sections therein which will assist in dewatering the product. As will further be understood by those skilled in the art, the apparatus will preferably also include one or a series of press rolls which will mechanically de-water the product sheet.

[0084] The sheet produced in forming box **216** will preferably be delivered to a drying system **218**. The drying system **218** will also preferably be of a type employed in the art for drying sheets of paper. Examples of suitable drying systems include but are not limited to: heated roll dryers; tunnel dryers; flash tube dryers; and combinations thereof.

[0085] A heated roll dryer employed in step **218** will preferably be of the type used in the paper or tissue industry and will preferably include a series of polished rollers heated with steam or heating media. Such rollers will typically have a stick-resistant coating. The number of rollers and temperatures employed

will typically depend upon the moisture content of the material and the particular evaporation rate desired.

[0086] If needed, the upper section of the roll dryer can be removed if the strength of the feather sheet is not sufficient to allow a significant amount of vertical travel. Alternatively, additional bonding agent resin can be used, for example, to increase the strength of the product.

[0087] If a tunnel dryer is employed in step 218, the air flow therein can be selectively directed either to urge the sheet product against the conveyor or to push the feather sheet away from the conveyor. As will be understood by those skilled in the art, the air flow direction selected will depend primarily upon the moisture level in the product sheet.

[0088] The dried feather sheet product can next be packaged in step 220 in generally the same manner and using substantially the same procedures as are used for packaging recycled paper. Thus, depending upon customer preferences, the sheeted product can, for example, be packaged as roll stock, as flat sheets, or as bales or can be compression baled or vacuum packed. Examples of uses of the feather sheet material produced by the present invention

include, but are not limited to, filler material, filter media, insulation, matting, and raw stock materials.

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[0089] An embodiment **250** of the inventive process and system for producing molded products is depicted in Fig. 5. The embodiment **250** depicted in Fig. 5 preferably comprises the same steps, procedures, and systems **152**, **154**, **156**, **158**, **160**, **162**, **164**, **166**, **202**, **204**, **206**, and **214** as employed in embodiment **200**. Embodiment **250** can also optionally include steps, procedures and systems **208**, **210**, and **212** used for adding reduced paper material to the feather slurry in tank **214**.

[0090] In embodiment **250**, slurry delivered from tank **214** will preferably have a feather to paper weight ratio of at least 2:3 and preferably not more than 19:1. The slurry will more preferably have a feather to paper weight ratio in the range of from about 4:1 to about 9:1 and will most preferably have a feather to paper weight ratio of about 17:3. The slurry delivered from tank **214** will also preferably have an overall solids concentration in the range of from about 1% by weight to about 10% by weight. The slurry will more preferably have a solids concentration of from

about 1.5 to about 7% by weight and will most preferably have a solids concentration of from about 3% to about 5% by weight.

[0091] In embodiment **250** of the inventive process, the refined slurry material from slurry tank **214** is preferably molded in step **252** and then dried in step **254**. The molding system or device employed in step **252** can generally be any molding system of the type employed for producing molded pulp products used for packaging. The molding system will most preferably be a vacuum mold system and will most preferably comprise a forming section which employs a vacuum to secure suspended fiber on the mold.

[0092] Examples of particularly desirable products which can be produced by inventive process **250** include, but are not limited to: egg cartons; bottle packaging; electronic packaging media; horticulture products; etc.

[0093] The drying system **254** employed for drying the molded feather products can generally be any dryer, oven, or other drying system employed in the art for drying similar products produced from paper or other materials.

[0094] After drying, the molded feather products can be packaged in step **256** using substantially the identical procedures and equipment employed for packaging the same products produced

from other materials. Examples of such systems include but are not limited to nesting devices such as those used for clustering egg cartons or flats.

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5 [0095] Thus, the present invention is well adapted to carry out the objects and attain the ends and advantages mentioned above as well as those inherent therein. While presently preferred embodiments have been described for purposes of this disclosure, numerous changes and modifications will be apparent to those skilled in the art. Such changes and modifications are encompassed within the spirit of this invention as defined by the appended claims.

10 [0096] It will also be apparent to those skilled in the art that the various process steps and features of the preferred
15 embodiments described herein can be used interchangeably to provide further and additional embodiments of the present invention.